Haystack Observatory VLBI Correlator

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Abstract This report summarizes the activities at the Haystack Correlator during 2014. Highlights include significant improvements in smoothing of operations through testing for best performance, fixing of operational bugs or problems, and the addition of new machines. Many broadband tests were also conducted, and the processing of the EHT March 2013 run continued, along with testing to prepare for new EHT observations in March 2015. Non-real-time e-VLBI transfers and DiFX and HOPS software support for other correlators continued.

1 Introduction

The DiFX VLBI correlator of the MIT Haystack Observatory, located in Westford, Massachusetts, is supported by the NASA Space Geodesy Program and the National Science Foundation. It is dedicated mainly to the pursuits of the IVS, with a smaller fraction of time allocated to processing radio astronomy observations for the Event Horizon Telescope (EHT) project. The Haystack correlator serves as a development system for testing new correlation modes, such as those needed for the VGOS observations, and for recorder developments, such as the Mark 6 system. Some software support is provided to similar DiFX installations at the U.S. Naval Observatory, to the Max Planck Institute for Radioastronomy in Bonn, Germany, and to the general IVS community for DiFX processing of IVS experiments.

MIT Haystack Observatory

Haystack Correlator

IVS 2014 Annual Report

2 Summary of Activities

2.1 DiFX Cluster Developments

Another data server with 60 TB of storage space was added to the available pool for storing incoming e-VLBI-transferred data, raising the total to $\sim$200 TB. Another compute server was added as well with the intention for it to become the master node. Over the last year, equipment that was used exclusively by the Mark IV was removed. Consolidation of Mark 5B Playback units (PBUs) and re-arrangement of equipment in racks has been an ongoing effort.

2.2 DiFX Production Improvements and Fixes

Efficiency has greatly improved over the last year through the smoothing of operations. This can be attributed to software development, such as modifying DiFX programs, e.g. ‘startdifx’, for more effective use with Haystack’s particular installation, and studying and optimizing maximum throughput methods given our cluster setup. One example is distributing station file data to separate file servers and playing back some stations from modules in order to spread the I/O load. As a result, the correlator runs with virtually no backlog attributable to throughput limitations. Also, some seriously debilitating bugs were identified and either fixed or patched around. Examples include problems processing Mark 5B data from modules (mark5bfix -1 problem discovered in DiFX version 2.3 and the trunk) and a problem with difx2fits handling polarization data coming from the EHT processing.

2.3 Broadband Delay

Numerous tests have been performed. In April the first test using RDBE firmware version 3.0 and complex format data was conducted. It was a success. Following that were two GGAO phase calibration tests, then a hiatus until October when an explosion of GGAO—Westford broadband tests began. Tests in October—November, which were designed to study different aspects of the broadband system, included setting all four UDCs at both stations to the same frequency to see how well the VLBI results compared between systems; stepping the UDCs in frequency to measure fringe amplitudes over 2.2—11.5 GHz; varying the power level into the RDBEs to test for level sensitivity in the VLBI results; and observing 4C39.25 using the channel select mode with minimum redundancy spacing and bands spanning 3.0—10.7 GHz. Then finally, two one-hour geodetic mode schedules were run using the setup described in the previous test. Mixed mode development for experiment RD1301 also continued.

2.4 DBE Testing

Testing of RDBE firmware version 3.0 and complex/VDIF format occurred as mentioned above. This configuration is now used in all broadband sessions. A newly designed ROACH-2 digital back end (R2DBE) and ancillary equipment, developed at the Harvard-Smithsonian Center for Astrophysics for the EHT project, were tested on the GGAO—Westford baseline in September. These equipment tests produced good fringes between the RDBE system recording 512 MHz of bandwidth vs. the R2DBE recording 2 GHz bandwidth. The recordings were cross-correlated using zoom mode in DiFX.

2.5 Mark 6

Another Mark 6 playback unit was added to the cluster, and use of Mark 6 has begun in the VGOS and EHT projects. In particular, all VGOS tests since January 2014 have used the Mark 6 recording system, as did the R2DBE tests described above.

2.6 Galactic Center Observations

Re-processing of the March 2013 EHT campaign on DiFX continues in order to compare it with the Mark IV correlator and to add the APEX station for which fringes were found much later. Also 3 mm tests of the LMT antenna and lab tests of R2DBEs and other South Pole telescope equipment were conducted as mentioned above.

2.7 Sejong Fringe Test

A fringe test was conducted using Hobart, Sheshan, and Sejong in order to commission the new antenna at Sejong, Korea, for routine IVS use. Results were good, and Sejong now participates in regular IVS sessions.

2.8 DSS-13 DVP Data Decoding

JPL designed and observed with a new digital back end, called the DVP, which recorded data in a different format than other DBE systems. DSS-13 used this system in the T2 experiments. Extensive effort was put into deciphering the setup of the station, which had configuration problems, and as a result good fringes were obtained.

2.9 DiFX Software Support

Support for the community continues for difx2mark4, fourfit, and HOPS. This support includes addition of features requested by users, other enhancements, and bug fixes.

2.10 e-VLBI

Non-real-time transfers have continued. Data from twenty sessions were transferred to Haystack this year from twenty-six stations: eight in Japan (Kashima34, Kashima11, Koganei, Tsukuba, Chichijima, Ishigaki, Aira, and Mizusawa), one in central Asia (Badary), eight in Europe (Simeiz, Svetloe, Zelenchukskaya, Onsala, Ny-Ålesund, Yebes, Wettzell, and Noto), three in Australia (Hobart, Yarragadee, and Katherine), one in New Zealand (Warkworth) two in South America (Fortaleza and Concepción (via Bonn)), two in South Africa (Hart15M and HartRAO) and one in Korea (Sejong). The number of e-VLBI transfer stations increased by six this year due to the addition of Yebes, Sejong, Simeiz, Badary, Svetloe, and Zelenchukskaya.

3 Experiments Correlated

In 2014, thirty-seven geodetic VLBI sessions were processed, at least in part, consisting of fourteen R&Ds, six T2s, and seventeen tests of various types. The test sessions included the broadband sessions and fringe tests and an assortment of other projects, some of which were touched on in the summary above. As usual, smaller tests were not included in the above count because they were too small to warrant individual experiment numbers. All production and test experiments were done on the DiFX cluster.

4 Current/Future Hardware and Capabilities

The DiFX cluster currently consists of six PCs, each with dual hex core 2.66 GHz Intel Xeon processors. Three file storage servers, which can also act as DiFX compute nodes, provide 200 TB of file storage. These are all connected through a 40 Gb/sec infiniband network fabric using a Qlogic switch. Currently six Mark 5B and two Mark 6 playback units with DiFX fully installed are connected to the infiniband fabric. We have processed up to 18 stations in one pass with this setup through a combination of playback units and files.

A large expansion of hardware capability is imminent. The addition of 16 computer servers, 40GigE ethernet fabric and more Mark 6 PBUs is planned, with all mentioned equipment either already in-house or their purchases pending.

5 Staff

Staff who participated in aspects of Mark IV, DiFX, Mark 5/6, and e-VLBI development and operations include:

5.1 Software Development Team

- Roger Cappallo - post processing; Mark 5B and 6; correlator software integration and troubleshooting; DiFX correlator development
- Geoff Crew - DiFX correlator development, post processing software; Mark 6
- Kevin Dudevoir - correlation; maintenance/support; Mark 5A/5B/5C; e-VLBI; computer system support/development; DiFX correlator development
- Jason SooHoo - e-VLBI; Mark 5A/5B/5C/6; computer system support
- Chester Ruszczyk - e-VLBI; Mark 5A/5B/5C/6
- Alan Whitney - system architecture; Mark 5A/5B/5C/6; e-VLBI

5.2 Operations Team

- Peter Bolis - correlator maintenance
- Alex Burns - playback drive maintenance; Mark 5/6 installation and maintenance; general technical support
- Brian Corey - experiment correlation oversight; station evaluation; technique development
- Dave Fields - filling in for Alex Burns while he takes a leave of absence at Ny-Ålesund (previously retired)
- Glenn Millson - correlator operator
- Arthur Niell - technique development
- Don Sousa - correlator operator; experiment setup; tape library and shipping

- Mike Titus - correlator operations oversight; experiment setup; computer services; software and hardware testing
- Ken Wilson - correlator maintenance; playback drive maintenance; general technical support

6 Conclusion/Outlook

A large expansion in compute servers and Mark 6 recorders is already underway. Broadband geodetic sessions at more regular intervals will be scheduled and processed in the near future and beyond that will include the addition of the new Kokee 12-m antenna with a new broadband system. EHT observations in March 2015 will also be a large processing load. Routine geodetic processing will continue as well.